Design of MEMS Tunable Capacitor all Metal Microstructure For RF Wireless Applications

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ABSTRACT

In this work a new design of a tunable capacitor based on microelectromechanical system (MEMS) technology is presented. The design of high Q- tunable capacitor has been accomplished through bulk micromachining process with all metal microstructure. A standard IC fabrication process (HP.5µ) is used to carry out the tunable capacitor. The main features of this high-Q MEMS tunable capacitor is the enabling of a complete monolithic fabrication of RF VCOs using on-chip IC compatible devices. Simulation results are presented to show the MEMS capacitor performance when used in RF VCO circuit. The tunable capacitor shows a high-Q of about 60 at 950 MHz of the VCO oscillating frequency.

Keywords:

RF VCO, RF MEMS devices, High-Q resonator, MEMS tunable capacitor.

1. INTRODUCTION.

Monolithic communication transceivers are highly desirable for today's wireless communication applications. However, current RF designs depend on off-chip components to implement key building blocks such as low phase noise RF voltage-controlled oscillators (VCOs). In most systems the oscillator employs discrete inductor and varactor diodes for frequency tuning. These off-chip devices rely on processing and materials that differ substantially from IC fabrication and consequently not suitable for monolithic integration, thus increasing cost, size and packaging complexity [1-2].

Continuing progress in technology specially miniaturization of both IC, and sensors and actuators, is enabling more and more microsystems to be realized. To date, some efforts have been made to exploit the microelectromechanical-systems technology for wireless RF applications. A passive component such as high Q tunable capacitor, high Q tunable inductor, and high-Q micromechanical resonator are reported in [3-6].

High-Q tunable capacitors are enabling components for wireless applications such as VCOs, PLL, and other RF circuits. The design approach of a high-Q tunable capacitor is based on controlling the gap area of the dielectric layer for achieving variable capacitance. MEMS with precise, µm- level movement are ideal drives for physical approach. A MEMS based switching diaphragm could be used as variable capacitor [3]. The range for this variable capacitance is limited because the top membrane could collapse onto the bottom plate. In [4] an electrostatic direct drive was used to control the air gap of the tunable capacitor, many such devices were connected in parallel to achieve the capacitance value typical for RF VCOs requirements. The key feature of the designed tunable capacitor presented in [5] is the use of indirect drive such as thermal actuation to control the gap variation. The capacitor plates used are designed from polysilicon which produce high insertion loss, and stray capacitance between the poly layer of the capacitor plate and the silcon substrate. A flip-chip is used to overcome of this problem which lead to extra fabrication cost.

In this paper we present, the design and fabrication of a high Q tunable capacitor. This MEMS tunable capacitor has been accomplished through building a bulk micromachining with metal microstructure using the standard IC batch processing. The advantages of using the bulk micro-machining is to prevent any stray capacitance between the capacitor plate and the silicon substrate which can affect the actual value of the tunable capacitor. Simulation results are presented to show the MEMS capacitor performance when used in RF VCO circuit.

2. THE MEMS TUNABLE CAPACITOR.

The cross sectional view and the 3-d view of the MEMS tunable capacitor is shown in fig. 1 (a), and (b), respectively. The Capacitor consists of a thin aluminum plate (250µm x250µm) suspended in air normally 1 -µm above a bottom aluminum plate with the same size through via. The bottom plate is contacted with thermal actuators from each side. Thermal actuators utilize the property of thermal expansion to produce motion. The difference in thermal expansion between two materials is used to get a deflection.. The optimal deflection depends on the actuator geometry, size, and overall configuration. The relation between the deflection and the biased voltage of the actuator is given in [7]. The thermal actuator considered in this work is designed from a polysilicon layer and a metal layer on top the deflection produced by this device can move the capacitor plate in ranges of 1-µm - 0.2-µm with a biased voltage ranges from 1-3 volts. When expansion on poly layer is produced, this cause the bottom plate to move up, consequent reduction of the air-gap, resulting in an increase in capacitance.

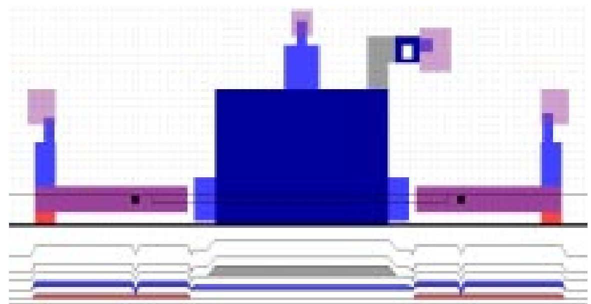

Fig.1a The cross sectional view of the MEMS capacitor.

The hole structure will be implemented through bulk micromachining using standard MEMS foundry (MOSIS). MOSIS now

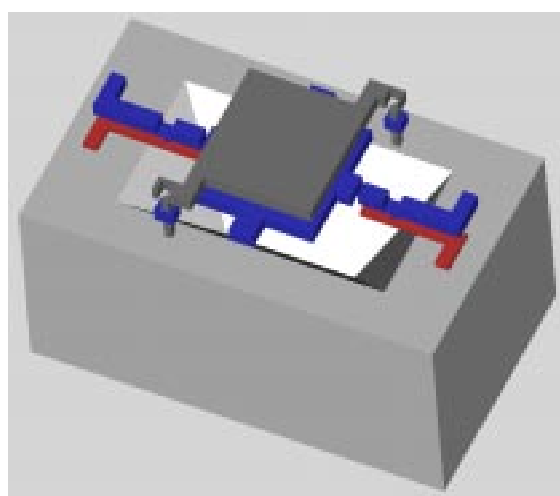

Fig. 1b The 3-D view of the tunable capacitor.

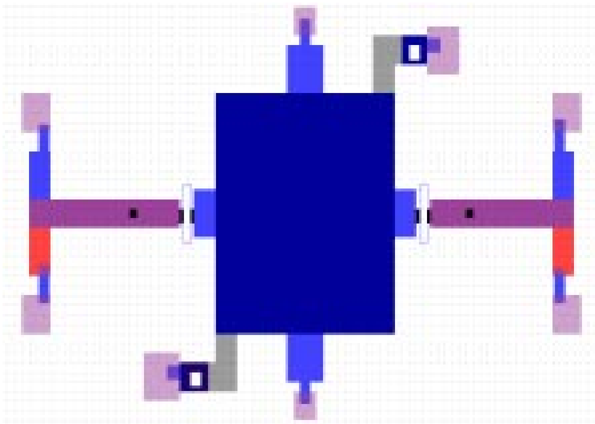

Fig. 2 The MEMS tunable capacitor layout, top view.

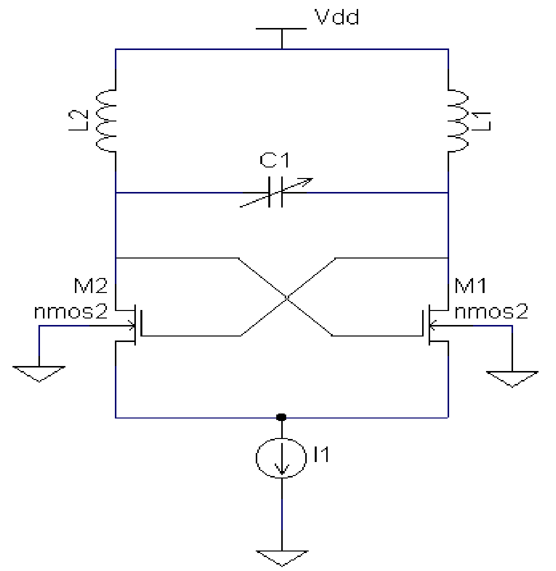

Fig. 3 The VCO circuit with the MEMS tunable capacitor.

Supports CMOS – compatible micro-machining to realize MEMS systems and devices. The advantages of using bulk micro-machining is to prevent stray capacitance between the capacitor plate and the silicon substrate which can affect the actual value of the tunable capacitor. The MEMS tunable capacitor layout is shown in fig 2.

3. SIMULATION RESULTS.

The designed tunable capacitor (250µm x250µm) has value of 2.5 pf. The MEMS tunable capacitor is tested in RF VCO circuit as shown in fig. 3 [8]. The simulation and the layout of the MEMS capacitor are carried out using tanner MEMS-PRO tools. The performance of the VCO is shown in fig. 4. This result shows that the tunable capacitor has high-Q value of 60 at 950MHz frequency application. The complete performance of the VCO circuit and the monolithic fabrication of the MEMS tunable capacitor and the VCO circuit using the MOSIS fabrication facilities (HP.5µ process) are given in details in [9].

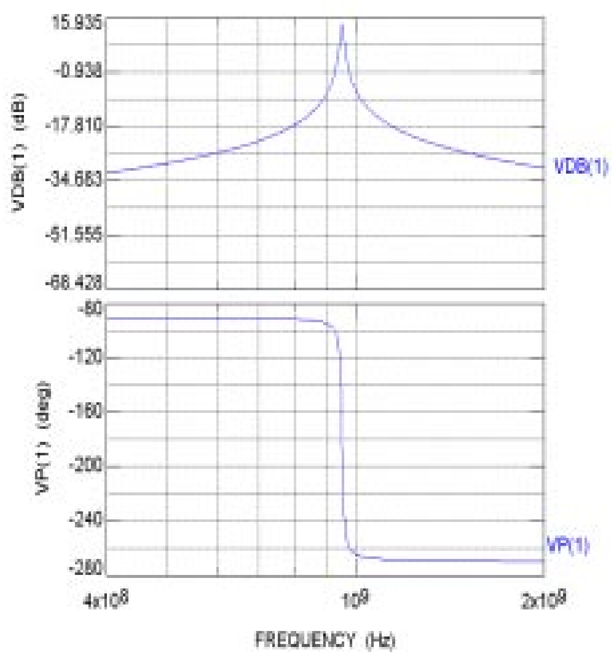

Fig. 4 The amplitude and phase vs. frequency of the VCO.

4. CONCLUSION.

In this work a MEMS tunable capacitor is designed for RF application. The MEMS capacitor is simulated in an RF VCO circuit and the simulation result shows its high-Q value of 60 at 950MHz oscillator frequency. The tunable capacitor is designed using metal microstructure, which contributes low resistance value about 0.06 Ω/μ m square that leads to better quality factor. The bulk micromachining process contributes low losses because of no stray capacitors between metal layer and substrate. An implementation of standard fabrication process for the RF MEMS tunable capacitor is considered. The benefits of realizing the RF MEMS device in a circuit's technology are not only to combine the MEMS device and the circuits on the same chip, but also it can be manufactured inexpensively, and their performance is enhanced by on-chip conditioning circuits.

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